Conservation of Energy Part 2

Where friction exists (i.e. everywhere on earth), heat and other forms of energy are produced, and must be considered when utilizing the conservation of energy theorem to solve problems.

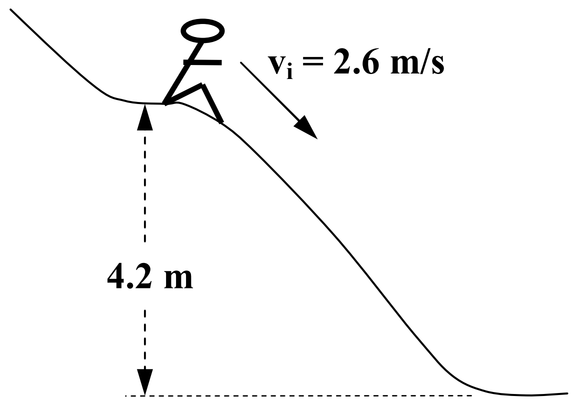
→ **total energy before = total energy after**

→ the sum of $\mathbf{E_p} + \mathbf{E_k}$ before = the sum of $\mathbf{E_p} + \mathbf{E_k}$ + **Heat etc.** after

Example #15: Consider the diagram to the right showing a 60 kg student on a large slide.

a) In the absence of friction, what would her speed be at the bottom?

b) If her actual speed at the bottom is 6.0 m/s, how much heat was generated on the section shown?

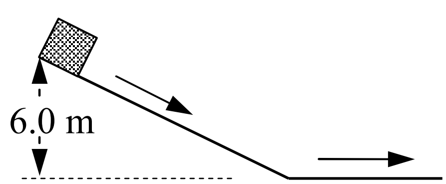


(see Work-Energy Ex 15 for answer)

Example #16: An object of mass 12 kg starts from rest and slides down a ramp that has a vertical drop of 6.0 m. Heat generated as the object moves down the ramp is 310 J.

a) How fast will the object be going at the bottom of the ramp?

b) If the object *then* slides along a horizontal surface of $\mu = 0.25$, how far will it travel before coming to a rest?



(see Work-Energy Ex 16 for answer)

Note that the total energy of the object at the start of the run is **mgh**, equal to **706 J**. At the end of the run, the entire **706 J** of energy has gone up in heat, lost to the atmosphere.

Efficiency

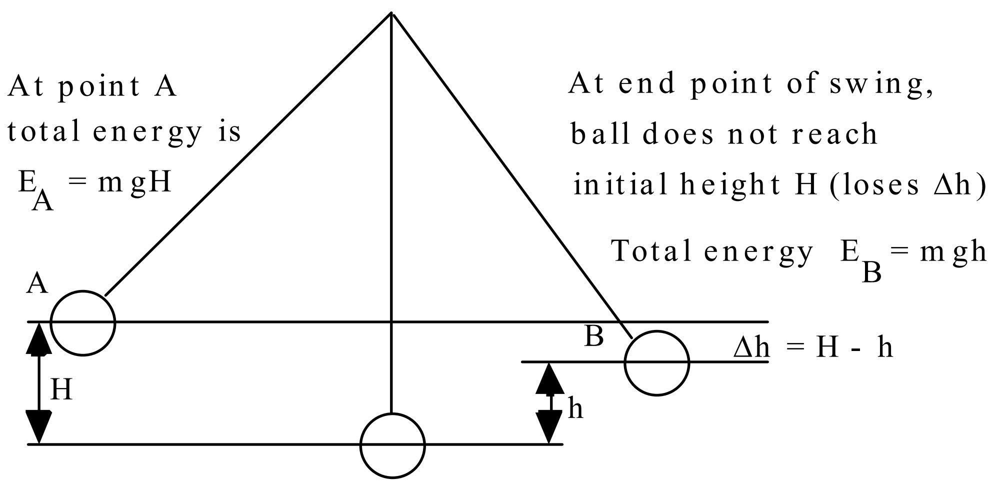
Because of heat generated (and essentially *lost*) due to friction, the energy left over as $\mathbf{E_k}$ and/or $\mathbf{E_p}$ is described as useful energy. *Efficiency* is a way of comparing the total energy a system started with to the useful energy retained or converted after the event is finished:

$$\textbf{Efficiency} = \frac{\textbf{useful energy transferred}}{\textbf{energy put in}} \times 100\%$$

Example #17: Consider the slide from Example #15. Using the information from part (b) only, what is the efficiency of this section of the slide?

(see Work-Energy Ex 17 for answer)

Example #18: In the following system, if H = 25 cm and h = 23 cm, what is the efficiency?



(see Work-Energy Ex 18 for answer)

Example #19: Find the % efficiency of a long hit baseball of mass 200 g; the ball leaves the bat at 18 m/s and is caught in the field (same height as when it was hit) at a speed of 14 m/s.

(see Work-Energy Ex 19 for answer)

Remember that any frictionless system will always have an efficiency of 100%. In essence, it is a perpetual motion machine which would ***never*** require any additional energy to maintain its motion.

Now consider the efficiency of a collision between two masses. In most cases, when two (or more) moving objects collide, some of their kinetic energy is lost to heat, sound, etc. as a result of the impact. Whatever kinetic energy exists after the collision is less than the kinetic energy between the objects before the collision took place.

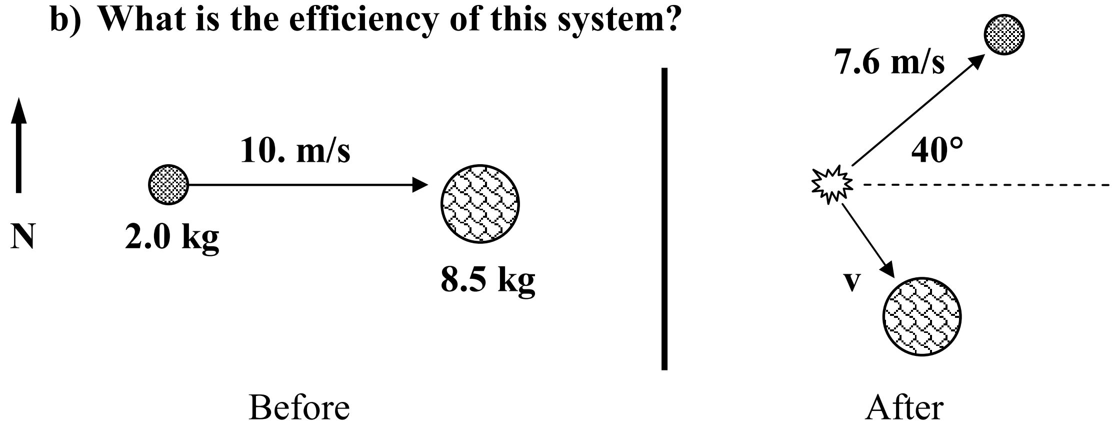
In other words, kinetic energy is NOT conserved in most collisions. However, there are a few exceptions to this rule – e.g., collisions between molecular and nuclear particles, repelling magnetic objects, as well as very hard materials such as ball bearings. Collisions of this type – where kinetic energy IS conserved – are described as *perfectly elastic*.

Some points you need to remember from this:

- problems involving perfectly elastic collisions can be analyzed using either conservation of energy or momentum. If the collision is not 100% elastic, ONLY conservation of momentum can be used to solve for unknowns.
- if two equal masses in an oblique collision (as above) show a 90° angle after the collision, that collision is perfectly elastic.

Example #20: A 2.0 kg ball collides at 10. m/s with a much larger stationary 8.5 kg ball as shown to the right. After the collision, the 2.0 kg ball changes its speed to 7.6 m/s @ 40° N of E.

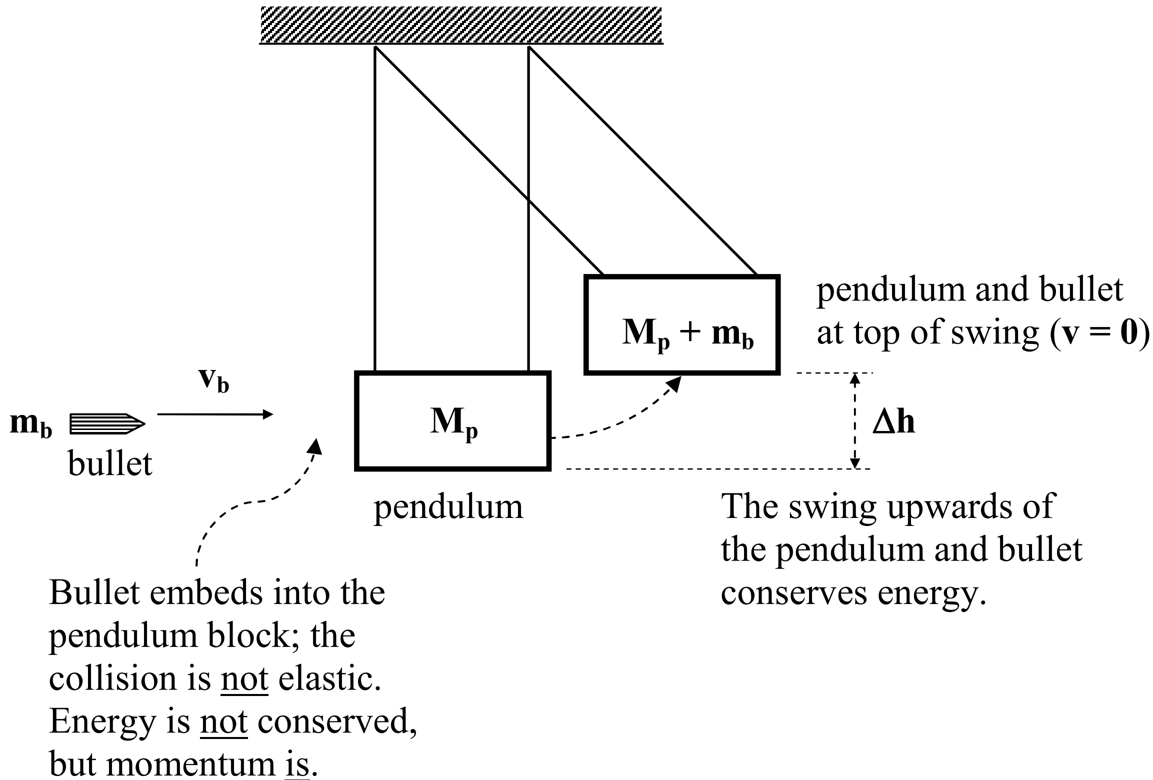
a) At what speed 'v' does the 8.5 kg ball move after the collision?
b) What is the efficiency of this system?



(see Work-Energy Ex 20 for answer)

The next and final problem nicely summarizes both aspects of conservation of momentum and conservation of energy. It is described as a *ballistic pendulum* problem.

In a ballistic pendulum problem, a bullet or arrow is shot into a stationary soft pendulum, which then swings upwards. The object is to find the speed of the bullet or the height reached by the pendulum.



Use these steps (not necessarily in this order):

- Use conservation of momentum to deal with the collision between the bullet and the pendulum, where:

  total momentum of bullet before collision
  = total momentum of block & bullet after collision

- Use conservation of energy to deal with the swing of the bullet and pendulum *after* the collision, where:

  total energy at bottom of swing (E_k) = total energy at top of swing (E_p)

Example #21: A 0.015 kg bullet is fired horizontally into a 3.0 kg block of wood suspended by a long cord. The bullet sticks in the block. Compute the original velocity of the bullet if the impact causes the block to swing 10 cm above its initial level.

(see Work-Energy Ex 21 for answer)